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DEPARTMENT OF COMMERCE

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METHOD AND COST OF QUARRYING LIMESTONE AT THE QUARRY OF THE TRINITY PORTLAND CEMENT CO., FORT WORTH, TEX.

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BY

J. WILLIAM GANSER

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METHOD AND COST OF QUARRYING LIMESTONE AT THE QUARRY OF THE TRINITY PORTLAND CEMENT CO., FORT WORTH, TEXAS[1]

By J. William Ganser[2]

INTRODUCTION

This paper is one of a series being prepared by the United States Bureau of Mines describing mining and milling methods and costs at cement-plant quarries throughout the United States.

These papers are designed to disseminate technical information regarding the methods used. The cost tabulations represent local operating expenditures only and not total production costs. It is recognized that publication of total production costs may in some instances cause embarrassment to individual producers as well as to the industry as a whole. On the other hand, operating costs are essential to the technical discussion and study of methods employed. The attention of the reader is specifically called to this differentiation in order that no misunderstanding of the scope of the cost tabulations shall ensue.

The methods described herein are those used at the Fort Worth Plant of the Trinity Portland Cement Co.

ACKNOWLEDGMENT

In the preparation of this paper the author wishes to acknowledge the assistance of Fred Burkett, civil engineer of the company, who furnished the drawings, and of J. M. Simmons, chief clerk, who supplied the cost data. Bulletin 1931 of the University of Texas, "The Geology of Tarrant County," by A. M. Winton and W. S. Adkins, was consulted for information regarding the geology.

1 - The Bureau of Mines will welcome reprinting of this paper, provided the following footnote acknowledgment is used: "Reprinted from U. S. Bureau of Mines Information Circular 6513."

2 - One of the consulting engineers, U. S. Bureau of Mines, and chief chemist, Trinity Portland Cement Co.

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HISTORY

The Trinity Portland Cement Co., of Dallas, operates three plants in Texas; one of which is in Dallas, one in Fort Worth, and the other in Houston.

In the spring of 1923 W. H. L. McCourtie, president of the Trinity Portland Cement Co., became interested in the possibility of building a cement plant in Fort Worth to supply the rapidly growing demand for cement in west Texas. After considerable prospecting south and north of Fort Worth, it was decided that the best lime rock and shale for cement purposes were north of Fort Worth.

A property consisting of 600 acres, about 5 miles north of Fort Worth was obtained and ground was broken in the fall of 1923 for the machine shop and stock room. In order to get a building on the ground quickly the old power house at the Dallas plant was dismantled and set up at Fort Worth. This old building had housed three 750-hp. Allis-Chalmers gas engines, which were being dismantled because of a gas shortage which resulted in the installation of a waste-heat power plant at Dallas. After the erection of this building at Fort Worth the work progressed slowly until the spring of 1924, when machinery began to arrive. Gradually during the following months the required buildings were erected and the machinery installed. Operation was started in the early part of May, 1925, and the first clinker was ground into cement on May 23.

In the layout of the plant the plan was to have all the buildings as close to one another as possible and to have everything compact so as to require the least amount of labor.

The plant is directly adjacent to the quarry which is situated on a gradual slope to a small creek which usually is dry during the summer. The only vegetation on this slope was sparse grass and cactus, and as there was little soil no stripping was necessary before opening the quarry.

GEOLOGY

The rock and shale are of the Washita division of the Comanchean series of the Cretaceous period. The shale or marl is called Kiamitia, and the rock is called Lower and Upper Duck Creek limestone. The highest points on the quarry have a thin layer of Fort Worth limestone.

These formations dip from the northwest to the southeast, at an inclination of about 50 feet to the mile.

The Kiamitia formation, as exposed under the Duck Creek limestone, is dark bluish, extensively laminated, and slightly calcareous. It is about 30 to 35 feet thick and where exposed weathers readily.

The following is an analysis of the Kiamitia shale found directly under the Duck Creek limestone:

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	Per cent
Silica	52.80
Iron oxide	2.86
Aluminum oxide	14.24
Calcium carbonate	19.08
Magnesium carbonate	2.45
Loss on ignition	6.59

Only the upper one or two feet of the Kiamitia shale is quarried but it has been found through cores that the bottom portion, which is next to the Goodland limestone, is a dark blue clay marl with bands of sandy, calcareous material. In the middle section are thin limestone layers and several calcareous sandstone flag layers each 2 or 3 inches thick.

The Lower Duck Creek formation is a series of compact, soft limestone strata. It is about 35 feet thick, and is characterized by a remarkable sequence of zones containing ammonites. These limestone strata are separated by many seams of a soft limestone 2 and 3 inches thick which easily disintegrate.

The following is an analysis of the limestone taken from one of these seams:

	Per cent
Silica	21.80
Iron oxide	3.45
Aluminum oxide	13.15
Calcium carbonate	53.52
Magnesium carbonate	1.50
Loss on ignition	5.10

Analysis of the Lower Duck Creek limestone is as follows:

	Per cent
Silica	6.02
Iron oxide	1.29
Aluminum oxide	3.38
Calcium carbonate	84.96
Magnesium carbonate	1.75
Loss on ignition	1.50

The Upper Duck Creek limestone or limy marl, at the present quarry face, is about 10 feet thick. It is a light colored, yellowish marl containing a conglomeration of fragmental limestone and has the following composition:

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	Per cent
Silica	17.70
Iron oxide	2.80
Aluminum oxide	9.20
Calcium carbonate	64.22
Magnesium carbonate	2.09
Loss on ignition	7.00

The quarry was first opened on the rim of an ampitheatre-like depression on the headwaters of a fork of Marine Creek which has cut back the Duck Creek and Kiamitia formations, thereby exposing the Goodland limestone in the creek bed.

METHODS OF PROSPECTING AND EXPLORATION

Previous to the purchase of the property considerable prospecting was done by persons expecting to interest someone in building a cement plant. What first probably attracted their attention was a 50-foot face of rock on Marine Creek about one-half mile north of the present quarry. Rock from this bluff was completely analyzed by us before we bought the property lower down the creek.

From the analyses we were convinced that Portland cement could be made from the rock in this locality. Two holes were drilled on the property, one 100 feet deep and the other 64 feet deep. The 100-foot hole showed 80 feet of limestone and marl and 20 feet of shale; while the 64-foot hole, which was drilled further down the slope showed 48 feet of rock and 16 feet of shale.

After the property was purchased we drilled six holes with a Cyclone drill to get more data as to the quality and thickness of the limestone. Samples from these holes showed that we had from 20 to 45 feet of rock over the area prospected. In each instance we drilled into the shale and all of the samples showed that it was quite uniform.

The following analyses were obtained on material from the deepest hole, each sample representing 5 feet of depth:

Analyses of material from deepest drill hole

Sample No.	Per Cent			
	Silica	Iron and aluminum oxide	Calcium carbonate	Magnesium carbonate
Rock:				
1	7.62	4.74	85.11	2.01
2	14.18	8.18	74.96	2.51
3	14.16	8.48	72.28	1.42
4	12.62	8.80	75.57	3.37
5	12.10	6.92	77.21	3.19
6	13.38	8.60	75.82	2.74
7	12.96	8.24	74.64	1.71
8	8.94	6.16	81.16	3.00
9	7.26	3.32	85.53	1.45
Shale:				
10	35.68	15.76	44.50	3.39
11	38.88	14.66	40.09	4.04

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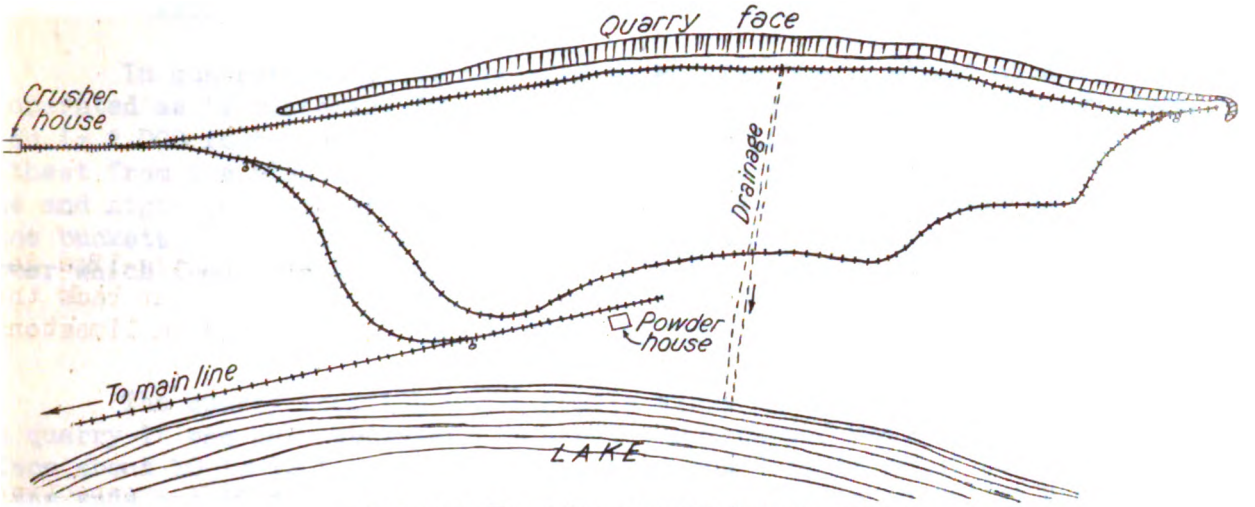

Figure 1.- Track layout and line of quarry face

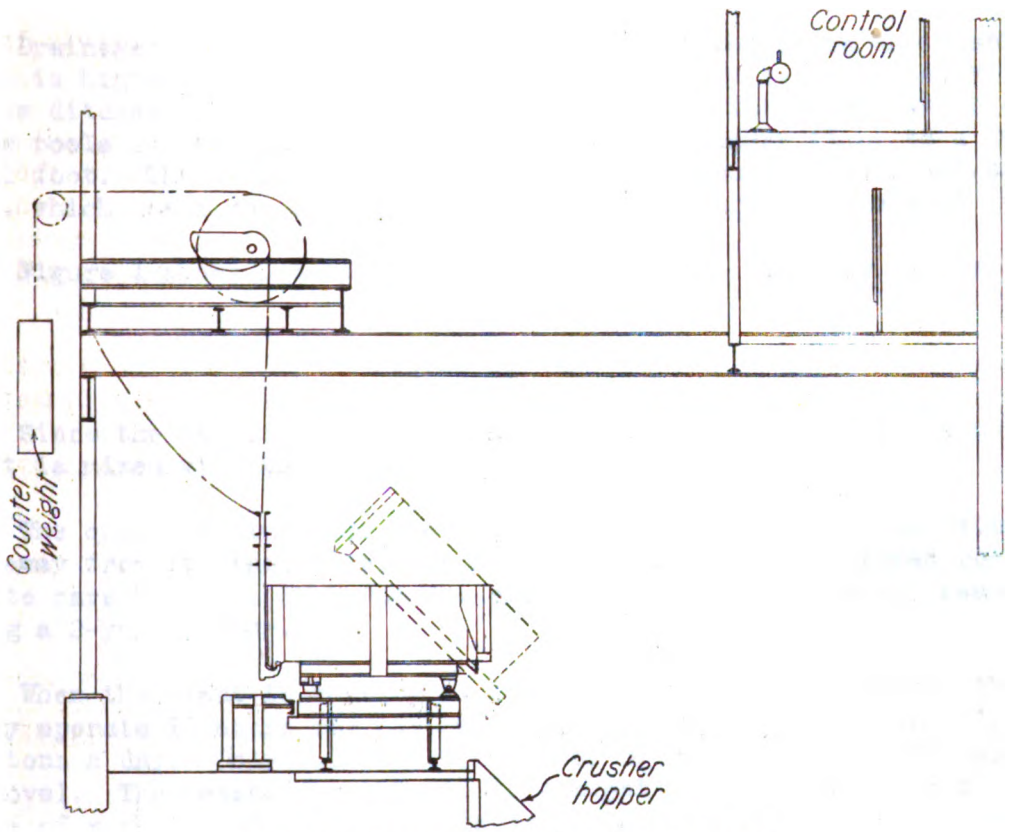

Figure 2.- Arrangement for dumping cars

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METHOD OF SAMPLING AND ESTIMATION OF TONNAGE AND VALUES

In quarrying, little shale is mined with the rock and no shale pit is operated as is customary in other cement-plant quarries. The quarry face, which is 2,000 feet long, contains rock and marl low in lime at the end farthest from the plant and slightly high in lime at the near end. The low-lime and high-lime rock are stored separately and mixed by taking so many crane buckets of one kind to so many of the other and dumping them into the hopper which feeds the tube mill.

CHOICE OF METHOD

The quarry location had a gentle slope and therefore in opening the quarry it was only necessary to shoot the rock and head the shovel into a face about 10 to 15 feet high. At present the face is about 30 feet high at the ends and 50 feet at the center. The rock face is worked in a straight line. The overburden nowhere amounts to over 6 inches. Of the 600 acres of land owned by the company 400 to 450 acres are available for quarry purposes.

Drainage of the quarry has been an easy matter since the floor of the quarry is higher than the creek bed and it has only been necessary to dig shallow ditches to carry the water to the creek. While some water stands in shallow pools in the quarry, it only softens the quarry floor to a depth of about 1 foot. There is a stratum of hard shale about 1 foot under the limestone, which keeps the shovel and ties from sinking into the soft shale.

Figure 1 shows how the track is laid out and the line of the quarry face.

MINING METHODS

Since the overburden is only about 6 inches in depth it is not removed, but is mixed with the rock when blasted.

The quarry begins near the end of the plant and the face extends straight away from it; therefore, the haulage is short. The broken rock is loaded into cars by a No. 50-B Bucyrus electric shovel on crawler treads and having a 2-yard dipper.

When the plant is running at full capacity it is necessary that the quarry operate 10 hours per day, six days a week, producing from 1,200 to 1,500 tons a day. Only 6,000 to 8,000 tons of rock are shot down ahead of the shovel. The reason for this is to prevent the water-soaking of large quantities of rock in wet weather, because if the rock is thoroughly wet the marly part becomes sticky and it is difficult to handle in the preliminary crusher.

While the rock face is 50 feet high at its maximum it is never this high after being shot. An effort is made to shoot the rock so that it is not usually over 30 feet high in front of the shovel. The width of the shovel cut is about 40 feet.

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DRILLING AND BLASTING

The rock is drilled in the usual way by putting down well-drill holes, for which a 4-inch Sanderson-Cyclone drill is used, electrically operated and on tractor wheels. This drill is operated by a 15-hp., 440-volt, 720-r.p.m., variable-speed motor.

The holes are drilled 14 to 16 feet from the face and down to the shale. Only one row of holes 16 to 18 feet apart is drilled at a time. These holes are shot one at a time, and only three or four are shot ahead of the shovel. This method of shooting was adopted to keep concussion to a minimum.

The drill bits are of tool steel, 4 inches wide with 45° slope on the drilling edge. Two men operate the drill 10 hours a day and drill about 120 feet. These men are paid by the hour, one receiving 40 and the other 30 cents. At this rate the labor cost is from 6¼ to 7 cents per foot drilled. As the holes vary from 20 feet to 60 feet in depth, the amount of dynamite put into a hole varies. The maximum amount put into a hole - a 60-foot hole - is one box or 50 pounds. All of the dynamite is put into the bottom of the hole, as it is the rock at the bottom that needs shattering. The top part - 1 foot to 10 feet - needs no shooting since it is a conglomerate of small rock and marl. When the bottom is shattered and pushed out by the shot, the top is easily broken up by the movement.

The dynamite used in these drill holes is 4 by 8 inch, 40 per cent gelatin. Cordeau-Bickford is used on all primary shots and is set off with a No. 6 detonator. The holes are all loaded in the usual manner, and tamped with dirt by a wooden pole on a rope.

Very little secondary shooting is necessary. The few rocks that are too large for the crusher are laid aside by the shovel and at some later time are shattered by "dobv" shots. From one to four 1¼ by 8 inch sticks of 40 per cent gelatin dynamite are placed on the large rocks with a fuse about 30 inches long and covered with mud.

LOADING STONE

All the stone is loaded by a No. 50 Bucyrus electric shovel with caterpillar tractors. A 100-hp., 2,200-volt motor drives a generator which delivers 230-volt current to a 60-hp. motor on the hoist of the dipper, a 13-hp. motor which swings the shovel, and a 13-hp. motor on the thrust. A 5-hp. motor on the dipper trip, a 2-hp. motor on the air compressor and 7½-hp. motor on the exciter are run by 440-volt current received through a transformer from the 2,200-volt leads. This system of motors is called the Ward-Leonard control. It is necessary to have only one man on the shovel and one man in the pit, who removes large rocks that might fall on the track and also signals with a flag to the tower man as to where to stop the electric car and when to move it after it is loaded.

When the quarry was first opened a No. 32 Marion steam caterpillar shovel, with a 1-yard dipper, was used. After several years this was too

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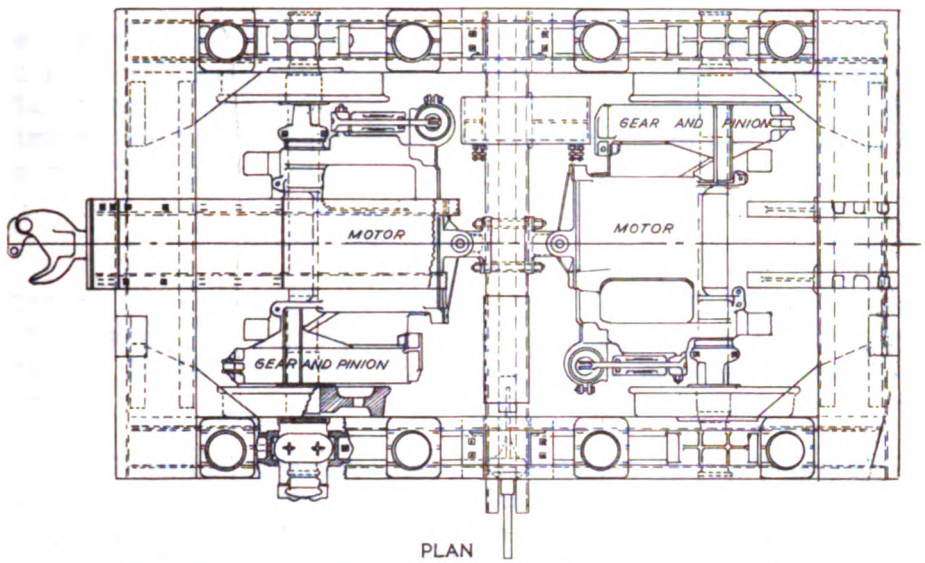
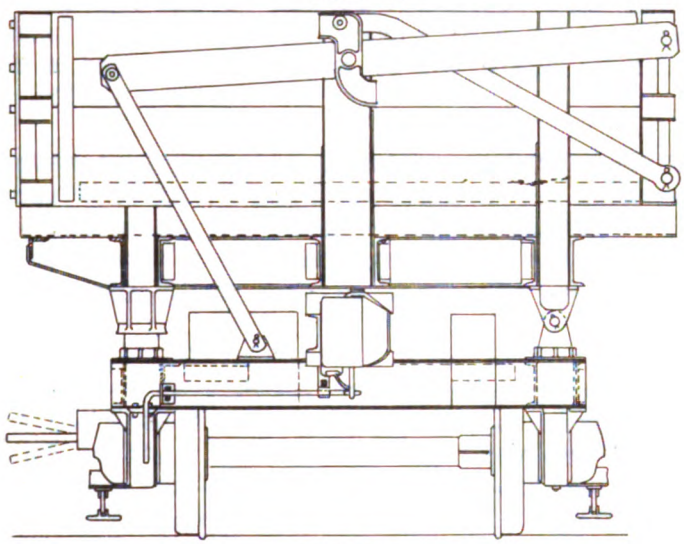
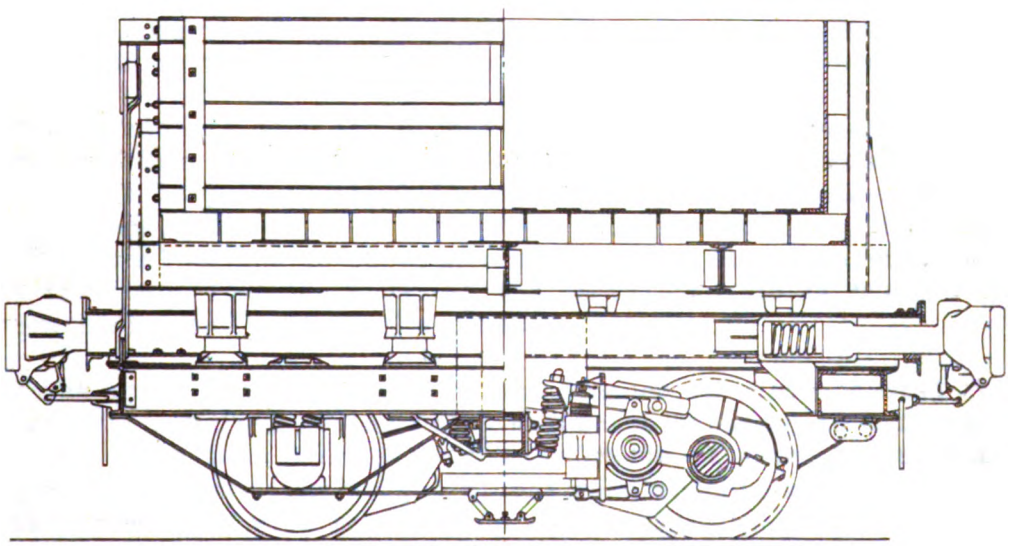


PLAN



END VIEW



SIDE ELEVATION

Figure 3.- Electric quarry car

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small to supply the quantity of rock necessary, and the bank became too high to operate so small a shovel safely. Since the crushing plant was being run entirely by electric power it was then decided best to purchase an electric shovel, thereby eliminating the necessity of maintaining a water line in the quarry and also the purchasing of coal.

TRANSPORTATION

Transportation from the quarry to the plant is by Woodford (electric) haulage system. This system, is controlled by an operator in a control tower which, in this instance, is in the plant above where the cars are dumped into the receiving hopper.

The cars, of 10-cubic yard capacity, were built by the Western Wheeled Scraper Co. They are of composite wood and steel construction and are of one-way, side-dump type. Each car has two 30-hp. Allis-Chalmers motors. Each motor drives an axle through direct single-reduction gearing. Three cars are being operated and each is equivalent in power to a 35-ton locomotive, as they will easily switch a box car of gypsum to the place of unloading. Figure 3 shows the design of the cars.

The Woodford system employs a third rail using 250-volt direct current. In some installations this third rail is between the haulage rails, but at this property it is placed on the outside of the rails. It was found that the third rail, when between the two haulage rails, interfered when switching box cars; therefore the third rail on the whole system was placed on the outside.

Operation of the system is simple, as everything is in full view of the tower operator from the time the cars leave the crusher building until they are loaded and returned to it. Each controller provides for three running speeds, one off position for coasting, and three brake positions for various brake pressures. With the controller handle in the off position a car will coast until the brake current is turned on. The controls are set so that the operator need not attend to the cars except for a few feet at the loading and discharge ends where they require accurate spotting. The three-speed control gives the cars a range of speed from 12 to 16 miles per hour.

The track system is composed of one track going from the crusher house to a switch, and two branches from the switch joining to form a long loop. One side of this loop is parallel to the face and is kept near it to serve as a loading track. The other is away from the face and is called the passing track. The usual method is to send empty cars out over the passing track and around the loop, spotting a car at the shovel as soon as the car before it has been loaded and sent to the crusher.

The device which dumps the cars at the crusher is also operated by the haulage man. It consists of two hooks which are attached to a frame and yoke. Two chains from this yoke go to cam-quadrants on which the chains wind as the quadrants revolve. The weight of the yoke and hooks is balanced by counterweights fastened to wire ropes which are wound on sheaves on the same shaft as the quadrant. When this shaft is turned by a motor (through

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gearing) the hooks are lifted, dumping the car sidewise, not only quickly but smoothly, and the car body is set back on the bolsters with very little jar. Figure 2 shows the design of the car-dumper.

CRUSHING PLANT

The cars are dumped into an 18 by 20 foot steel-lined hopper from which the rock is discharged by a pan-type feeder, driven by a 5-hp., 440-volt motor, to a No. 7 Mammoth Williams hammer mill, driven by a 250-hp., 2,200-volt, 750-r.p.m. motor. Feed to hammer mill consists of pieces ranging from a 3-foot cube to 1/8 inch in size.

The discharge from the Williams mill is elevated by a 42-inch pan elevator, driven by a 25-hp., 2,200-volt, 720-r.p.m. motor, and discharged onto a short belt 30 inches wide driven by a 5-hp., 440-volt, 720-r.p.m. motor, which carries the rock over a wall into the rock storage.

Following is a screen analysis of the discharge from the Williams mill:

Size of mesh passed,	Per cent
1½ Inch	89.5
1 "	84.5
¾ "	75.7
½ "	67.7
¼ "	59.0
1/8 "	30.2
20 Mesh	16.7
30 "	9.5
50 "	5.6
100 "	2.7

The rock after arriving in storage is either put into the section for low-lime or high-lime rock, or taken to the bins feeding the tube mills. The rock storage is 75 feet wide and 178 feet long and has a capacity of 10,000 tons. This rock is moved in storage by a Shepard 6-ton traveling crane equipped with a 3-yard clamshell bucket. This crane has a span of 75 feet and is equipped with a 10-hp., 1,200-r.p.m., 440-volt trolly motor, two 40-hp., 900-r.p.m., 440-volt hoist motors, and a 40-hp., 900-r.p.m., 440-volt, bridge motor. All of these motors have variable speeds.

As already stated, the quarry is arranged so that high-lime and low-lime rock mixtures may be made. These mixtures can be further varied by adding different proportions of the rock from the crane bin, all of which makes for uniformity and for less correction after the raw material has been ground into slurry.

The two tube mills for grinding the raw mixture are adjacent to the rock storage and are fed from a hopper loaded by the crane. They are 8 by 30 foot Traylor combination mills, each driven by a 700-hp., 2,200-volt, 180-r.p.m. motor. These mills each have three compartments, so that the

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reduction is in three stages. The total weight of the grinding media per mill is 70 tons, of which 20 tons of 2 by 4 inch balls are in the first compartment, 20 tons of 1½-inch balls are in the second compartment, and 30 tons of 1 by 1¼ inch slugs are in the third compartment. The balls consumed per ton of material ground amount to 0.304 pound. Tube-mill liners last from two to three years. The raw slurry from the mills contains 40 per cent of moisture, and 90 per cent of it will pass a 200-mesh screen. The two mills grind at the rate of 29.39 tons per hour, or 14.70 tons per mill per hour.

The slurry from the mills flows to a bucket-elevator pit from which it is elevated to silos, where it is agitated before being fed to the kilns and burned at 2,700°F. into Portland-cement clinker. Figure 4 shows the flow sheet from the quarry to the kilns.

WAGE SCALE

No regular foreman is employed in the quarry, the superintendent, or mill foreman, supervising when necessary. The quarry men receive wages as follows:

Position	No. of men	Wages per hour
Shovel operator	1	$0.65
Pitmen	1	.35
Driller	1	.40
Driller's helper	1	.30
Powderman	1	.50
Crusher-tender	1	.40
Crusher-tender helper	1	.30
Towerman	1	.60
	8	

SAFETY ORGANIZATION

The idea of safety is being brought to the men at this plant in an unusual but impressive manner. All those guilty of breaking the safety rules if found out appear at a court held each Monday morning and are tried for the offense. The following is a description of this court, by J. M. Simmons:

> A judge is elected to preside over the court, select the jury, appoint the prosecuting attorney, and perform such duties as befall a judge in regular court. A sheriff is elected, who, incidentally, is a man whose regular duties as an employee require that he go through the entire mill several times a day. It is the duty of the sheriff to see if he can detect any employee doing a careless act or anything that may endanger himself or his fellow workers. Should he discover anything of this nature he files charges with the court clerk, who issues a notice to the man to appear at the next meeting of the court to answer the charge turned in by the sheriff. The sheriff also notifies any witnesses that he is able to find. Any employee in the mill can file charges, through the sheriff and court clerk.

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At five minutes to 10 o'clock each Monday morning, at our regular safety period, the plant whistle blows; indicating that the men in each department selected by the department foreman are to appear in the court room - our regular first-aid room. The foreman has no trouble whatever in getting the men to come to the court, for they would all come if allowed.

The meeting is called to order promptly at 10 o'clock, and the minutes of the previous meeting are read by the secretary. We then have a short discussion on ways and means of preventing accidents, asking for suggestions from the men. We get our best recommendations from the men who do the actual work where hazards exist. These recommendations are put in the minutes of the meeting and are read the following week, giving account of those carried out.

The meeting is then turned over to the judge (shipping foreman), who opens the court by giving a brief talk on the purpose of the court stating that it is not intended to create any personal feeling, but that it is all in a spirit of fellowship and good will.

The judge then has the first case on the court docket read by the clerk, asks for corrections, appoints a jury, swears in the witnesses, and turns the case over to the prosecuting attorney. The prosecuting attorney and the attorney for the defense (selected by the defendant) have 10 minutes each to question the witnesses of both sides and the defendant himself, and five minutes each to sum up and plead the case to the jury. When the defense rests the case, the jury retires to the jury room for not more than three minutes, after which time it returns a verdict of guilty or not guilty.

If the defendant is found guilty, the judge lectures the prisoner on safety work and particularly on safety work in line with the case just tried, which lecture incidentally is for the benefit of the entire court.

In the fall of 1929 practically the entire plant was given first-aid training by the U. S. Bureau of Mines. Since then six men have formed a first-aid team and have on several occasions entered first-aid contests in Fort Worth and Dallas.

Accident record of the plant since 1927

Year	Days lost per 1,000 man-hours	Man-hours worked
1927	0.528	261,542
1928	0.109	301,378
1929	0.403	431,670
1930	0.000	371,752

ADMINISTRATION ORGANIZATION

Figure 5 shows the organization chart for the entire plant.

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Table 1. - Summary of costs

Trinity Portland Cement Co., No. 2. Period: Jan. 1, to Dec. 31, 1929.

Total material loaded during period: Overburden - - - included with stone
Stone - - - - - 294,883 tons (2000 lbs).

Operating costs per dry ton of stone mined

	Labor	Air drills	Power costs	Explo-sives	Other supplies	Total
Mining:						
Drilling	$0.0082	$0.0008	$0.0002	-	$0.0006	$0.0098
Blasting	.0058	-	-	$0.0250	-	.0308
Loading	.0203	-	.0015	-	.0075	.0293
Transportation	.0306	-	.0028	-	.0119	.0453
Crushing	.0139	-	.0087	-	.0121	.0347
Grinding	.0341	-	.1191	-	.0274	.1806
Elevating	.0029	-	.0005	-	.0048	.0082
Conveying	.0029	-	.0005	-	.0011	.0045
Miscellaneous plant	.0147	-	-	-	-	.0147
Total operating costs	.1334	.0008	.1333	.0250	.0654	.3579
Depreciation	.0300	-	-	-	-	.0300
Depletion	.0100	-	-	-	-	.0100
Taxes	.0100	-	-	-	-	.0100
Insurance	.0100	-	-	-	-	.0100
Miscellaneous overhead	.0200	-	-	-	-	.0200
Total costs	.2134	.0008	.1333	.0250	.0654	.4379

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Table 2. - Summary of costs in units of labor, power, and supplies

Period: Jan. 1 to Dec. 31, 1929.

Material loaded during period: Overburden - - - - - - - - included with stone.
Stone - - - - - - - - - - - - - - 294,883 tons.

	Mining	Crushing	Total
A. Labor (man-hours per ton):			
Drilling	0.0215		0.0215
Blasting	.0142		.0142
Loading	.0330		.0330
Haulage	.0534		.0534
Miscellaneous	.0111		.0111
Total labor	.1332		.1332
Average tons per man per shift			47.52
Labor, per cent of total cost			37.24
B. Power and supplies:			
Explosives (lbs. per ton)			.1639
Total power (kw.h. per ton) 1/			14.0196
Shovels	.0015		.0015
Haulage 2/	.0028		.0028
Drills	.0008		.0008
Crushing		0.0087	.0087
Elevating		.0048	.0048
Conveying		.0011	.0011
Tube mills		13.9999	13.9999

1/ Average cost of power is $0.008 per kilowatt hour.
2/ Power includes that used on both locomotives and electric haulage system.

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Table 3. - Detailed average shovel costs, direct operation

Period: Jan. 1 to Dec. 31, 1929.

Type of shovel, 50-B Bucyrus; size of dipper, 2-yard.

Stone loaded, tons 294,833.

	STONE COST	
	Total	Per ton
Engineers	$3,002.25	$0.0102
Pitman	1,394.35	.0047
Other operating labor		
Total operating labor	4,396.60	.0149
Fuel or power	454.12	.0015
Grease and lubricants	199.29	.0007
Coal - crane expense	735.50	.0025
Total supplies	1,388.91	.0047
Shovel-repair labor	1,587.40	.0054
Repair supplies	1,283.96	.0043
Total repairs	2,871.36	.0097
Total shovel operation	8,656.87	.0293

Table 4. - Detailed summary costs - direct operation

Period: Jan. 1 to Dec. 31, 1929.

	STONE COST	
	Total	Per ton
Total all shovels	$8,656.87	$0.0293
Drilling:		
Operating labor	2,357.20	.0080
Air, Gas, Power	69.90	.0002
Operating supplies	168.50	.0006
Repair labor	60.15	.0002
Repair supplies	229.00	.0008
Total drilling	3,723.23	.0098
Blasting:		
Labor	1,697.30	.0058
Explosives	7,372.71	.0250
Other supplies		
Total blasting	9,070.01	.0308
Haulage:		
Locomotives	3,533.40	.0119
Cars	1,531.31	.0051
Track maintenance	8,359.58	.0283
Haulage	13,424.29	.0453
Grand total	$34,036.00	$0.1152

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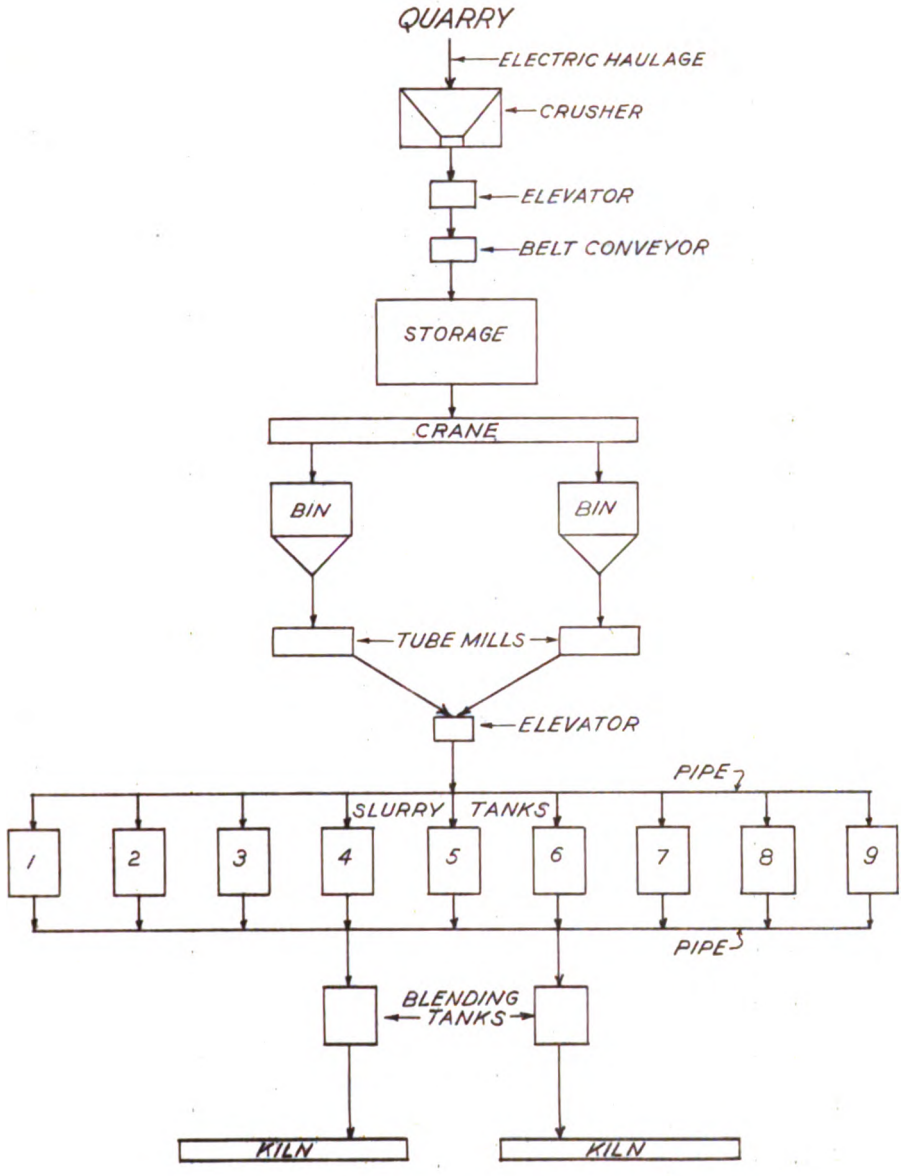

Figure 4.- Flow sheet

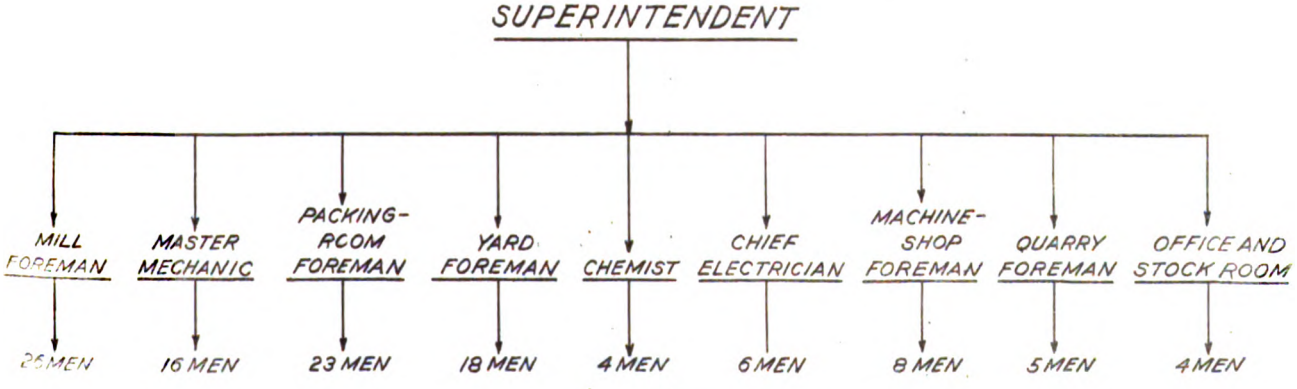

Figure 5.- Organization chart

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